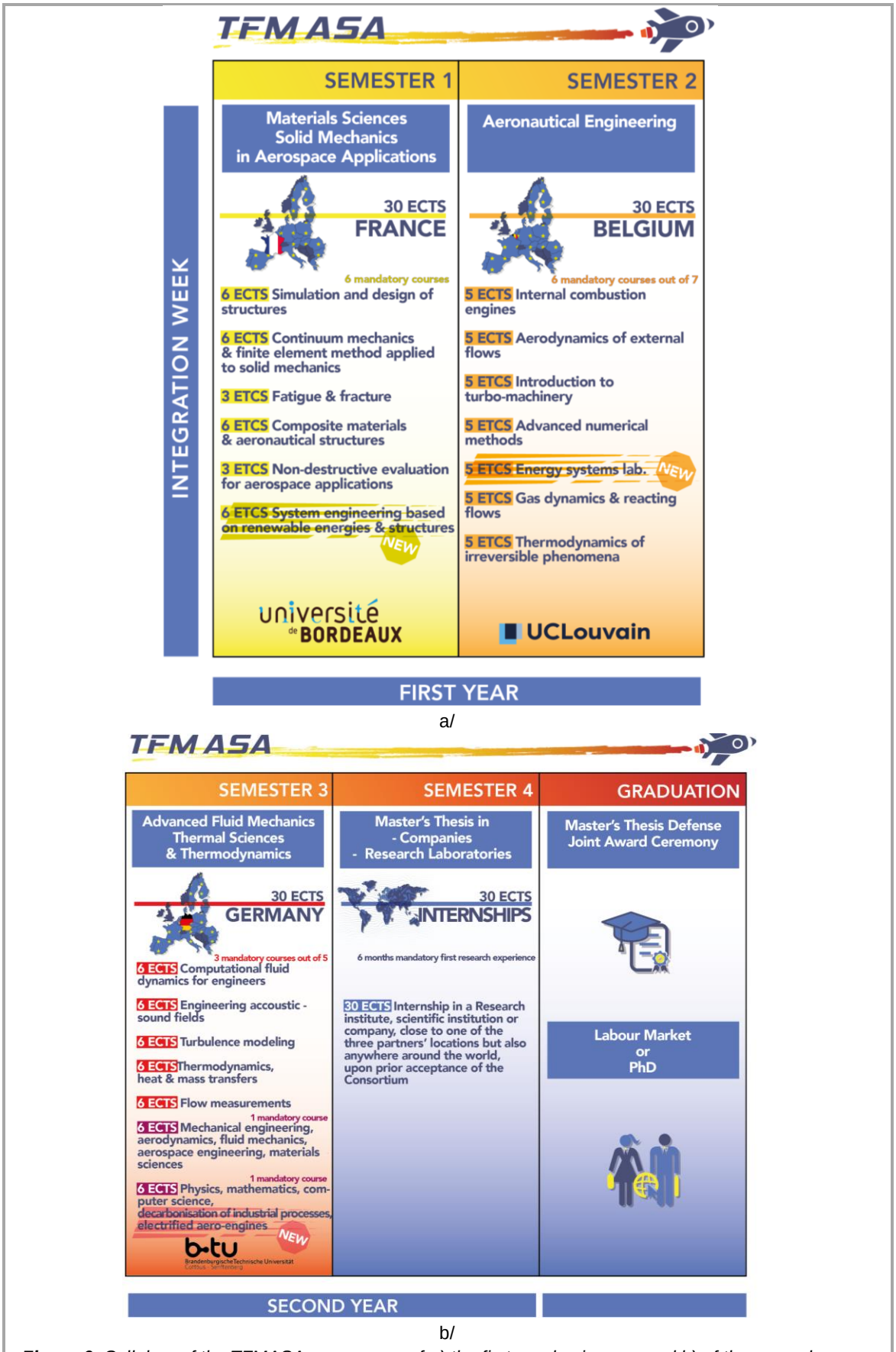

Figure 6: *Syllabus of the TFMASA programme of a) the first academic year, and b) of the second year.*

1st SEMESTER of the 1st year of the Master's programme – UBx, FRANCE

All courses are compulsory

- **Simulation and design of structures - 6 ECTS**
  → Lectures: 8h - Practical works: 10h – Labs: 36h

From the functional requirements and technical specifications of a product (geometrical configuration, materials and load cases), the students should be able to (i) write and justify assumptions from a physical point of view and to propose a Finite Element model, and to (ii) implement the model and analyse the product's response in order to validate or optimise its structure. Industrial lectures, related to structural analysis in industrial product development and innovation, are proposed.

- **Continuum mechanics and Finite Element method applied to Solid Mechanics - 6 ECTS**
  → Lectures: 20h - Tutorials: 16h - Lab: 15h

An *"Introduction to Mechanics of Continuous Medium"* part deals with the notions of continuity, deformations, and external forces acting on a solid media or fluids, the constitutive relation and associated modelling through some examples whereas another part entitled "*Finite element theory and application"* explains how to construct a stiffness matrix, to assemble elementary matrix with introduction of boundary conditions (variational approach, applications on industrial code: Abaqus).

- **Non-Destructive Testing (NDT) - 3 ECTS**
  → Lectures: 6h remote classes + 2h in face-to-face ones - Tutorials: 8.5h - Lab: 15h

After introducing definitions, objectives, application areas and certifications, the principles of different NDT techniques are exposed as visual inspection, penetrant testing, magnetoscopy, ultrasonic, Foucault current, x-ray, thermography. Some particular cases are treated (composite materials, microelectronics).

- **Fatigue and Fracture - 3 ECTS**
  → Lectures: 24h

The objectives are the introduction of the concepts of (i) rupture and fatigue used for structures' damage tolerance design, and those for (ii) modelling and designing structures against fatigue crack initiation. The course is divided in 2 parts: *"Linear elastic fracture mechanics"* and *"crack initiation under multiaxial fatigue in metallic materials".*

- **System Engineering based on Renewable Energy and Structures - 6 ECTS**
  → Lectures: 24h - Tutorials: 16h - Labs: 36h

The first part consists in introducing the renewable energy sources (solar, wind, biomass…), the technical and environmental aspects of related systems and technologies (PV panels, Betz law, BEM, electrical aspects and so on), and in comparing the energy conversion technologies. The second part is related to system engineering addressed *via* industrial case studies.

- **Mechanics of composite materials and structures for aerospace applications - 6 ECTS**
  → Lectures: 17.5h - Labs: 20h

The first part is dedicated to criteria definition for material and composite materials selection and technical specifications (composition, properties). The second part relates to the analysis and design of aeronautical structures through the theory and applications of thin-walled structures, models for plates and shells, structural stability.

2nd SEMESTER of the 1st year of the Master's programme: UCLouvain, BELGIUM

6 of the 7 courses are compulsory

- **Internal combustion engines - 5 ECTS**
  → Lectures: 12 x 2h, Labs: 12 x 2h (including tutorials, practical works, exercises)

The students should be able to integrate the various branches of mechanics allowing to structure the description of internal combustion engines, to master their conceptual aspects and to model their behaviours.

- **Aerodynamics of external flows - 5 ECTS**
  → Lectures: 12x2h, Labs: 12x2h (including tutorials, practical works, exercises)

The course deals with the aerodynamics/hydrodynamics of external flows (advanced fluids mechanics) through the physical comprehension of the problems and phenomena, their modelling in an adequate mathematical formalism. The student should be able to develop the aptitude of working outside of directed class sessions and to produce quality and concise written reports.

- **Gas dynamics and reacting flows - 5 ECTS**
  → Lectures: 12 x 2h, Labs: 12 x 2h (including tutorials, practical works, exercises)

The goal is to understand and use elements of supersonic combustion and detonation dynamics for the study of explosions, and of systems for hypersonic propulsion. The student should be able to use the concepts of gas dynamics for the analysis of propulsion systems (including non-linear waves: shock waves, rarefaction waves and contact surfaces), and those of compressible flows for the analysis of the aerodynamics of aircrafts and rockets.

- **Introduction to turbomachinery - 5 ECTS**
  → Lectures: 12 x 2h, Labs: 12 x 2h (including tutorials, practical works, exercises)

The focus of these lectures is directed towards axial steam and gas turbines through concepts of thermodynamics, compressible flows, kinematics and so on. The fundamental principles of design and operation of axial and radial turbomachines (compressors, turbines, steam turbines) are explained.

- **Advanced numerical methods - 5 ECTS**
  → Lectures: 12 x 2h, Labs: 12 x 2h (including tutorials, practical works, exercises, code projects)

The objective is to get the students acquainted with innovative numerical methods through integral methods for solving wave-like problems, finite element methods for solving shallow water systems, adaptive grids, multigrid solvers, and particle methods for granular flows. In the practical organisation, a great importance is given to collaborative projects. Flexibility is highlighted to focus on a problem-solving approach.

- **Spacecraft and mission design - 5 ECTS**
  → Lectures: 12 x 2h, Labs: 12 x 2h (including tutorials, practical works, exercises, code projects)

This course aims at covering the various challenges encountered in the design of a spacecraft to be in line also with the integration of sustainability and renewable energies in this field: Astrodynamics, Mission design, Propulsion, Science instruments, Telecommunications, Electrical power systems, Attitude, Structures, Thermal and Space environment.

- **Thermodynamics of irreversible phenomena - 5 ECTS**
  → Lectures: 12 x 2h, Labs: 12 x 2h (including tutorials, practical works, exercises)

A general theoretical framework of irreversible phenomena having as starting points the kinetic theory of gases and classical thermodynamics is presented, as well as the classical theory of Onsager-Prigogine among the more recent theories. A specific learning outcome is a modern approach to non-equilibrium thermodynamics and to a unified description of thermal, mechanical, viscous, and electromechanical processes to enhance the students' synthetic skills.

- **Energy - 5 ECTS**
  → Lectures: 12 x 2h, Labs: 12 x 2h (including tutorials, practical works, exercises, seminars)

Specific learning outcomes are memorisation of the main orders of magnitude and units in the field of energy and the identification and understanding of the parameters required to characterise the performance of energy systems and technologies, in terms of technical, environmental, economic, societal, and ethical aspects. Seminars are led by experts from within or outside UCLouvain, and then prepared and supervised by different groups of students. Beyond the technical aspects, the themes are also related to the links between energy/economy, the philosophical roots of the energy/ecological crisis, the energy situation in Africa, the combined heat and power heating, the new generation nuclear reactor and nuclear wastes.

3rd SEMESTER of the 2nd year of the Master's programme: BTU, GERMANY
3 of the 5 courses are compulsory

- **Computational Fluid Dynamics (CFD) for Engineers - 6 ECTS**
  → Lectures: 30h - Tutorials: 30h - Self-organised studies: 120h

The students should be able to understand the topics of industry-related CFD from an analytical and practical point of view. The work with industry-relevant software is brought into focus and enables the students to deal extensively with the content. The students should be able to independently create and evaluate CFD simulations, and to draw conclusions about their applicability to industry.

- **Engineering Acoustics – Sound Fields - 6 ECTS**
  → Lectures: 30h - Tutorials: 30h - Self-organised studies: 120h

The students should gain an insight into the theoretical treatment of the propagation of sound and acquire an in-depth knowledge of noise control of vehicles, aircrafts and machinery using sound insulation, attenuation, and damping.

- **Turbulence Modelling - 6 ECTS**
  → Lectures: 30h - Tutorials: 30h - Self-organised studies: 120h

The students should acquire the knowledge of different approaches to model turbulent flows. They should be able to decide which turbulence model is adequate for different applications.

- **Thermodynamics, Heat and Mass Transfers - 6 ECTS**
  → Lectures: 30h - Tutorials: 30h - Self-organised studies: 120h

The goal is to solve tasks independently and to know methods of attaining new perceptions in thermodynamics and heat and mass transfers to apply the theoretical formalisms.

- **Flow Measurements - 6 ECTS**
  → Lectures: 30h - Tutorials: 30h - Self-organised studies: 120h

The students should acquire the basics of optical flow measurements for Fluid Mechanics and Aerodynamics. They should be able to apply the basic methods and measurement techniques to solve experimental Fluid Mechanics and Aerodynamics problems.

2 of the 9 courses are compulsory

- **Computational Fluid Dynamics (CFD) 1 - 6 ECTS**
  → Lectures: 30h - Tutorials: 30h - Self-organised studies: 120h

The students should be able to understand the basic concepts of numerical flow simulation. In the practical works, they learn to apply methods to solve sample problems in computational fluid dynamics.

- **CFD Project - 6 ECTS**
  → Lectures: 30h - Tutorials: 30h - Self-organised studies: 120h

The hands-on training aims at conveying basic knowledge of scientific computing through the application of CFD software. Students work independently on separate projects, deepen their basic knowledge of CFD methods and learn the sequence of operations of programming, compiling, executing codes, and post processing data.

- **Decarbonisation of Industrial Processes - 6 ECTS**
  → Lecture: 30 h - Study project: 30 h - Self-organised studies: 120 h

The students should be able to understand the challenges of CO_2-reduction in the industrial sector. Readiness of current and emerging technologies are discussed, and technology options are evaluated. The students should be able to name the requirements for achieving climate goals in the industrial sector.

- **Dimensional Analysis and Experimentation - 6 ECTS**
  → Lecture: 30 h - Study project: 30 h - Self-organised studies: 120 h

The goal is to use dimensional analysis to bring together the results of experiments and theory/computations in a concise, but exact, form, for many phenomena in nature, engineering or society exhibit the remarkable property of self-similarity.

- **Electrified Aero Engines - 6 ECTS**
  → Lecture: 30 h - Tutorials: 30 h - Self-organised studies: 120 h

The students should get a deeper inside into the technology background and aviation requirements of disruptive means for novel propulsion systems to minimise the climate impact of civil aviation. The lecture tackles air transport vehicles up to the size of a regional aircraft.

- **Experiments in Aerodynamics and Fluid Mechanics - 6 ECTS**
  → Lecture: 30 h - Tutorials: 45 h, Self-organized studies: 120 h

The students should be able to understand the basic aerodynamics and fluid mechanics phenomena as well as measurement techniques that are state of the art from an analytic and a practical point of view.

- **Image Based Measurement Techniques for Aerodynamics - 6 ECTS**
  → Lecture: 30 h - Tutorials: 30 h - Self-organised studies: 120 h

The students should acquire the optical and electronic basics as well as suitable digital image processing and evaluation methods for various 2D- and 3D-image based measurement and visualisation methods for aerodynamics in order to exploit the experimentally achieved instantaneous or time-resolved planar or volumetric flow field data from industrial flow facilities or wind- and water tunnels, which leads to a deeper understanding of the investigated flow properties and related (dynamical) forces and moments.

- **Stochastic Methods for Flow Simulations - 6 ECTS**
  → Seminar: 30 h - Self-organised studies: 150 h

After successful module participation the students are able to apply stochastic methods to numerical problems in fluid mechanics. Contents The theoretically and numerically covered subjects are stochastic mixing models (e.g. LEM and HIPS) and stochastic turbulence models (e.g. ODT and ODTLES).

- **Waves and Instabilities in Fluids - 6 ECTS**
  → Lecture: 30 h - Tutorials: 30 h - Self-organised studies: 120 h

The students should master the foundations of hydrodynamics with regard to theoretical and phenomenological aspects. The topic serves as an example for studying the realisation of knowledge and the classification of knowledge within the field of physics.

Mobility scheme and requirements

The master lasts two academic years (120 ECTS) with at least 2 mobilities, including a master's thesis associated with current academic research activity or high-level industrial projects. This **mobility in 3 different European countrie**s during the TFMASA master, and **to other countries including the non-European ones through internships or co-tutored theses** makes students participate in the **dissemination of European values and culture**. It promotes also the **diversity of scientific cultures to nurture interpersonal skills, particularly creativity and innovation**. At the same time, it enables the students acquiring knowledge and understanding of the state of the art in all areas in which the partner departments have acknowledged expertise. Our students gain substantial expertise in one particular area, for example in energy issues related to aeronautics applications. The courses are given by academic personnel and they are completed by seminars provided by international leading experts and professionals from industry.

Figure 7 gives an overview of the mobility scheme:

- The 1st semester consists of Solid/structural Mechanics – Materials Science courses (30 ECTS). It takes place at the University of Bordeaux in France,
- The 2nd semester consists of Aeronautical Engineering courses (30 ECTS). It takes place at UCLouvain in Belgium,
- The 3rd semester consists of Advanced Fluids Mechanics, Thermal Sciences and Thermodynamics courses (30 ECTS). It takes place at Brandenburg University of Technology in Germany,
- The 4th semester is related to the internship, Master's thesis (30 ECTS). It takes place wherever in the world.

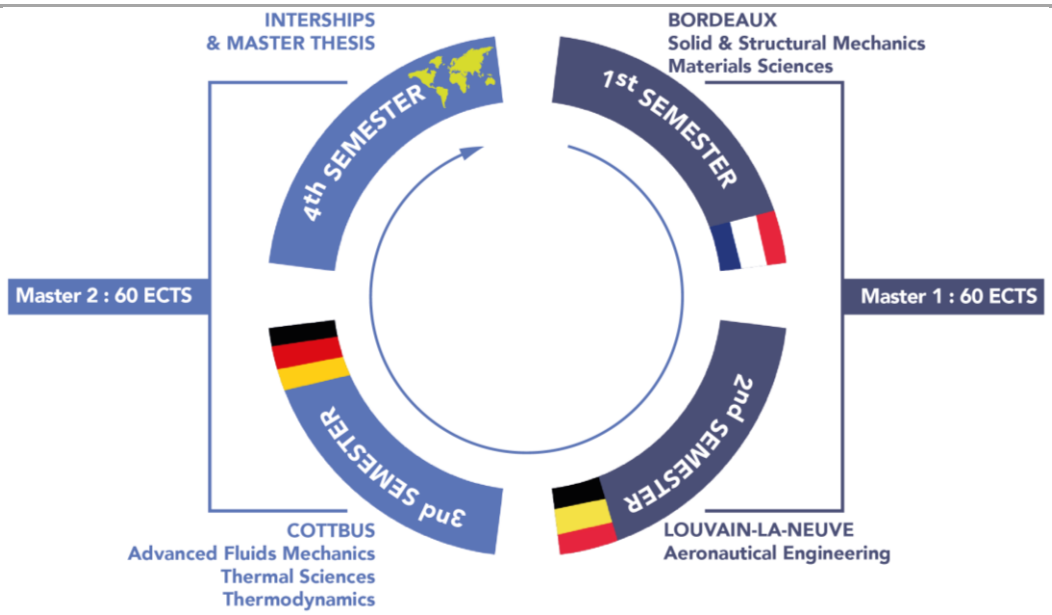

Figure 7: *Overview of the mobility scheme of the International Master TFMASA.*

Jointness in application, selection and student scholarship allocation

Joint application and selection

The students' candidatures are organised *via* **the online application eMundus** (www.emundus.fr/) already used by several other Master Mundus programmes running at UBx. The platform is open from around late October to beginning of February and is a major help to organise the process. In February, the project manager in Bordeaux performs an initial **administrative check** to ensure students meet the eligibility requirements defined by the consortium. Thereafter, she/he attributes the eligible applications to the academic evaluators who will perform the **evaluation *via* the common criteria**, described briefly below. After the administrative check, the eligible candidates are evaluated by two academic reviewers from each partner university. **If a student withdraws her/his application**, her/his place in the Programme will be offered to the next candidate on the waiting list.

The students are selected according to their Curriculum Vitae, transcripts of records, motivation letter, recommendation letters and knowledge in sciences. The three partners select **more than 20 students** according to the following criteria:

- Excellence of the academic curriculum (40%),
- Coherence between the academic background and/or the professional experience of the student and the programme content (30%),
- Motivation, international mobility and open-mindedness of the student (30%).

The partners have together determined the following joint selection criteria:

- students need to hold a valid Bachelor or Engineering School degree in Mechanical Engineering or Physics training,
- a good level in sciences, particularly in solid and fluid mechanics, thermal sciences, thermodynamics and material science is required,
- students from non-English speaking countries must provide an official letter from the university confirming that English is the language of instruction. For the other students, the TOEFL or IELTS tests must be passed before applying for the Master. For TOEFL, a minimum of 550, 213 or 79 points for paper-based, computer-based and Internet-based TOEFL/TOEIC test is required, respectively. Marks of at least 6.0 (out of a total of 9) are required for IELTS test.

The Academic Board makes then a **final selection** in April of the eligible applicants' list according to the selection criteria detailed hereinabove, sorted in ascending order, to reach the **target of 20 participants for one cohort**. A selection remote meeting is set up to work on the final ranking. The best-ranked students are offered the Erasmus Mundus scholarships whereas the other pre-selected students by the